VITAMIN A CONTENT OF THE LIVER OF THE AUSTRALIAN SEA LION *NEOPHOCA CINEREA* (PÉRON) AND ITS TOXICOLOGICAL SIGNIFICANCE

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Summary

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Analyses are presented of the vitamin A (retinol) content of the liver of a series of females of the southern Australian sea lion, *Neophoca cinerea* (Péron). These show a range of 79-11,964 IU/gm of wet liver (four specimens). These figures are comparable with the previously recorded levels of vitamin A in the livers of certain species of seals in which the consumption of liver is known to be responsible for toxic effects in man. The significance of these figures is discussed, and comparisons made with data for some other carnivores. Figures are also presented for the serum vitamin A levels of *N. cinerea*, of 0.3-2.0 μmol/l (five specimens). A significant correlation ($P = 0.05$) between the weight of the seal and the log. (serum vitamin A level) is found in the series.

KEY WORDS: Liver vitamin A, toxicity, Australian sea lion, *Neophoca cinerea*.

Introduction

Various species of vertebrates are known to accumulate high levels of vitamin A (retinol) in the liver. Thus certain species of sharks and fishes have been exploited commercially as sources of vitamin A. Various mammals have also been recorded as having levels of vitamin A in the liver such that human toxicities have followed the ingestion of amounts of liver which may be customarily consumed at a meal. Among such mammals are the sperm whale, *Physeter catodon* (L.) (Moore 1967), the polar bear, *Thalarctos maritimus* (Phipps) (Rodahl & Moore 1943; Rodahl 1949a,b,c; Russell 1967), and various species of Arctic seals and other carnivores, such as the Arctic fox, *Alopex lagopus* (L.) and the husky, *Canis familiaris* L. (Southcott *et al.* 1971).

It is generally considered that such an accumulation of vitamin A represents the end of a food chain involving cartonoid accumulation and metabolism. Human intoxications resulting from such ingestions have been considered important in the ecology of the Eskimo, and accidental poisonings from such sources have affected the history of polar exploration in both the Arctic and Antarctic regions (de Veer 1598, 1609; Rodahl 1949c; Halstead 1965, 1970; Cleland & Southcott 1969b; Shearman 1978).

Among the seals or Pinnipedia, some species have been identified as having livers toxic, or possibly toxic, on ingestion by man, e.g. the Arctic bearded seal, *Erignathus barbatus* (Erxleben), the Greenland seal, *Phoca groenlandica* Erxleben, while other species, such as the Atlantic grey seal, *Halichoerus grypus* (Fabricius) and the Weddell seal, *Leptonychotes weddelli* (Lesson), have been shown to have much lower levels of hepatic vitamin A, such that ingestion in quantities which may customarily be eaten is unlikely to cause symptoms (Rodahl & Davies 1949; Rodahl & Moore 1943; Southcott *et al.* 1971; Southcott 1975, 1979).

For purposes of discussion, we may consider that a "hearty meal" of liver or other equivalent meat could weigh 500 g.

Southern Australian records of toxicity associated with human ingestion of seal liver

In southern Australian waters there has been evidence suggestive of toxicity following the eating of seal liver since the early days of European settlement. Thus Leigh (1839) recorded, after a visit to South Australia in 1937, that in the aborigines "... fatal consequences often ensue from their feasting on seal, especially the lion white seal, the flesh of which kills dogs in twenty minutes, and is not to be eaten with impunity by any until it is quite putrid, when, they say, it is harmless. I myself have eaten the black hair seal, when fresh meat was scarce, but it was a young one, which ... made but a bad meal".

This report probably originated from the Encounter Bay district of South Australia. Although Leigh (1839) made no reference to

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the liver as having been the part of the seal flesh associated with the toxicity, yet it would seem probable that such toxicities followed the eating of liver (see the discussion in Cleland & Southcott 1969a).

In various parts of the world there have been records of toxicities that have followed the eating of seal meat, and in many cases there is reference to the liver as the suspected cause of the toxicities. Commonly these stories relate to shipwrecked sailors, or isolated castaways or explorers, so that rarely does the opportunity of submitting such data to more exact analyses occur.

As an example of this Péron (1816) recorded that, on King Island in Bass Strait, which the Baudin expedition visited in December, 1802, a group of English sailors had discovered, in the case of the then numerous elephant seals, *Mirounga leonina* (L.): "With regard to the liver, which is sought after in some species of seals, in the sea elephant it seems to have some noxious substance: for the English sailors having tried to eat it, experienced an overwhelming drowsiness, that lasted several hours, and which re-occurred [e]very time that they partook of this treacherous food" (translation of Miecc 1971, p. 32).

It was not until 1971 that analyses of the vitamin A content of the liver of this species were made, indicating a toxic level (1080, 1240 IU/g of wet liver: two specimens) (Southcott *et al.* 1971). The mean of these two readings is 1160 IU/g. Accepting this figure, then 500 g of wet liver would contain 580,000 IU, which is somewhat lower than the figure generally accepted in the past, of 1,000,000 IU, as representing a toxic dose for an adult; however vitamin A levels in the liver of most species tested have shown a considerable variation; this is discussed further below.

At the present time the range of the southern elephant seal, *M. leonina*, is generally considered a subantarctic one, and the southern coastlines of Australia are only rarely visited by stragglers. However, it is apparent that before European settlement of Australia, it was present in some numbers in the offshore islands of mainland southern Australia and Tasmania.

In southern Australian waters the Australian fur seal, *Arctocephalus pusillus doriferus* Jones is at the present time confined to the coasts of the south-eastern part of the continent (King, 1969; Stirling & Warneke 1971). This is now considered a subspecies of the Cape fur seal, *A. pusillus* (Schreber) of South Africa. Studies of the hepatic vitamin A content of *A. pusillus doriferus* have been made by Southcott *et al.* (1974), who recorded a range of 360-15,000 IU/g of wet liver (mean = 2711 IU/g; S. D. = 2835 IU/g; n = 30).

More extensive studies on the hepatic vitamin A content of the Cape fur seal, *A. pusillus pusillus*, have been made in the Republic of South Africa and in South-West Africa, where the livers of this seal were processed commercially for their vitamin A yield, over 1941–1949 (as well as for their skins and blubber oil) (Shaughnessy 1981) (see further below, Table 4).

The much rarer species of southern Australian seal, the southern Australian sea lion *Neophoca cinerea* (Péron, 1816), survives in small populations on offshore islands of South and Western Australia (Stirling 1972a, 1972b; Ray & Ling 1981). Only recently have specimens of this species become available for a detailed study of the hepatic vitamin A content. The results of this investigation are detailed below.

Technical methods

The seals were captured as part of a scientific study programme to be recorded in full elsewhere, including studies on morphology, biochemistry, reproductive physiology, and other aspects, including trace elements and pollutants analyses.

In each case approximately 100 g of liver was taken immediately after death from pentothal anaesthesia, and placed at once in a polythene bag, preserved in solid CO_2 (−78.5°C), and transferred to refrigerator storage (at −16 to −20°C) until the analyses were made. Samples of serum were taken at the same time, and preserved similarly, for later analyses.

The vitamin A analyses have been made by the Carr & Price (1926) method, and the serum vitamin A levels by the fluorometric procedure of Hansen & Warwick (1968).

Results

Five specimens of *N. cinerea* were taken. Each was a female. Data on the location and date of capture, the weight, length and girth recorded, the hepatic vitamin A content and

TABLE 1. *Data on the vitamin A analyses, location data, and physiological status of five specimens of the southern Australian sea lion,* Neophoca cinerea (Péron).

Serial No.	Collectors' master No.	Locality	Date	Weight (kg)	Length* (cm)	Girth (cm)	Liver vitamin A content (IU/g, wet liver)	Serum vitamin A level (μmol/l)	Physiological state
NC1	AS23	Dangerous Reef, S. Aust.†	28.x.80	60.6	155.5	91.5	79	0.3	Not lactating Embryo present
NC2	—	Dangerous Reef, S. Aust.	28.x.80	76.7	—	—	—	0.3	No data
NC3	AS24	Dangerous Reef, S. Aust.	29.x.80	65.3	157.0	78	1 185	0.3	Pregnant; foetus aged 3 months present
NC4	AS25	Seal Bay, Kangaroo Island, S. Aust.†	18.iii.81	87.1	158.5	—	5 818	2.0	Lactating, with 8-weeks-old pup
NC5	AS26	Seal Bay, Kangaroo Island, S. Aust.	18.iii.81	94.8	163.0	—	11 964	1.6	Lactating, with 6-weeks-old pup
Means							4 761.5 (n = 4)	0.9 (n = 5)	

* Curvilinear length measured according to the method of the committee on Marine Mammals (1967).
† Collected by J. C. Fanning, A. Nicholson & J. K. Ling.

TABLE 2. *Correlation matrix for weight, curvilinear length, log. (liver vitamin A content) and log. (serum vitamin A level) for four specimens of* Neophoca cinerea.

Variate	weight	curv.-length	log. (liver vit. A)	log. (serum vit. A)
weight	1.0000			
curv.-length	0.9111*	1.000		
log. (liver vit. A)	0.9189*	0.8566	1.0000	
log. (serum vit. A)	0.9545†	0.7488	0.8427	1.0000

* Significant at the 10% level of probability.
† Significant at the 5% level of probability.

the serum vitamin A level, and notes on the physiological state of the animal, are presented in Table 1.

Submitting the four variates weight, curvilinear length, log. (liver vitamin A content) and log. (serum vitamin A level), for the four animals NC1, NC3, NC4 and NC5, to a correlation analysis produces the correlation matrix in Table 2.

There has thus been found a significant degree of correlation between: (1) weight of the animal and its curvilinear length ($P = .10$); (2) weight of the animal and the log. (liver vitamin A content) content ($P = .10$); (3) weight of the animal and the log. (serum vitamin A level) ($P = .05$). (Since the series includes only four animals, it appears reasonable to utilize the 10% level of probability as well as the 5% level in drawing inferences.) If the variate weight is replaced by weight 1/3 a similar correlation matrix is generated, with the same levels of probability in the comparisons as shown for the weight.

In a previous study it was found that in a group of 24 females of the fur seal *Arctocephalus pusillus doriferus*, there was a significant degree of correlation between the log. (hepatic vitamin A level) and the weight of the animal (Southcott *et al.* 1974). (The logarithm of the vitamin A content of the liver was chosen then because of the highly skew distribution of the liver vitamin A levels; it is

therefore thought appropriate to use the logarithms of the vitamin A variates for study in the present work.)

Discussion

In the past it has been not uncommon for it to be stated in textbooks of medicine or pharmacology that a toxic dose to man is represented by 1,000,000 IU of vitamin A. Although this is a realistic figure for acute toxicity in a child, in an adult a more realistic figure for a dose which can cause acute toxicity is in the range 2,000,000-5,000,000 IU (Hayes & Hegsted 1973). It has appeared to me for some time that since most intoxications following the ingestion of seal and other carnivore liver are in respect to adults, a realistic dose representing acute toxicity could be accepted as 3,000,000 IU.

In Table 3 is shown the amounts of liver (wet weight) which are equivalent to 1,000,000 and 3,000,000 IU of vitamin A, for the four specimens of the present study.

TABLE 3. *Amounts of liver of* Neophoca cinerea, *as wet weight, equivalent to 1 000 000 and 3 000 000 IU of vitamin A.*

Seal specimen	Equivalent to 1 000 000 IU		Equivalent to 3 000 000 IU	
	g	lb	g	lb
NC1	12 658	27.9	37 975	83.7
NC3	843.9	1.86	2 531.6	5.58
NC4	171.9	0.38	515.6	1.14
NC5	83.6	0.18	250.8	0.55

The upper ranges of the vitamin A content of the sea lion liver (Table 1) represent amounts that are toxic on ingestion at a single meal, i.e. the amount of 250 g or 0.55 lb of liver is easily consumable by an adult with a hearty appetite at a single meal, if we accept that 3,000,000 IU of vitamin A is a toxic dose.

The present study has therefore confirmed a report made as long ago as 1837 that the flesh of the southern Australian sea lion (in the form of liver) may be toxic on ingestion.

The point may also be made that since vitamin A is a cumulative poison, acute doses lower than those nominated above may result in symptoms of acute toxicity, if the subject has had an above-average intake of vitamin A beforehand. This suggestion was discussed from the evidence of Antarctic expeditions by Cleland & Southcott (1969b, p. 1342) in relation to the illnesses of members of the Australasian Antarctic Expedition of 1911-1914, notably in Mertz and Mawson. Similar considerations apply to other groups of persons living isolated lives and with a high intake of certain species of fishes or their predators in their diets. According to Mandel (1975, p. 1573) "a daily intake exceeding 50,000 μg of retinol [equivalent to about 167,000 IU of vitamin A] frequently results in toxic effects in adults". It is therefore not necessary that there should be an acute intake of any nominated quantity of vitamin A for symptoms of acute hypervitaminosis A to be precipitated in a pre-conditioned subject.

Variation in the vitamin A levels within a number of species of terrestrial and marine carnivores

Rodahl & Moore (1943) first established that the traditionally-known toxicity of polar bear liver (among the Eskimos) could be a result of the high vitamin A content of that organ. A number of subsequent workers have published data on the vitamin A levels of the levels of a number of Northern and Southern Hemisphere carnivores, substantiating the evidence from other sources of the toxicity of the liver in certain species, on ingestion by man. One feature of the published estimates has been the wide variation in the hepatic vitamin A level. Several of these results are shown in Table 4.

The data for the hepatic vitamin A levels in a range of carnivores indicate a wide variation, suggesting that there may not be a "normal" level for this substance, and that extrinsic and possibly other factors influence the levels. Inaccuracy of an analytical laboratory is one factor that needs to be considered. However, the tests for vitamin A content are usually comparatively simple chemical and colorimetric ones. In the case of the widest range shown in the figures in Table 4, that for *Neophoca cinerea*, repeated study confirmed the accuracy of the figures given.

Another possible factor which could be responsible in some cases is decomposition of the vitamin A under the influence of inadequate temperature control, and rancidity of the oil containing it. Again, in the case of the *N. cinerea* estimates, care was taken to exclude such a cause of variation by meticulous attention to preservation at a low tem-

TABLE 4. *Vitamin A levels in the livers of a selection of Northern and Southern Hemisphere carnivores.*

Carnivore	Minimum and maximum published figures of vitamin A levels (IU/g of wet liver)	Reference source	Ratio of maximum: minimum estimates
Thalarctos maritimus polar bear	13 000–34 600	Rodahl & Moore (1943) Rodahl (1949a) Russell (1967)	2.66
Erignathus barbatus Arctic bearded seal	12 000–14 000	Rodahl & Moore (1943)	1.17
Phoca groenlandica Greenland seal	600–12 000	Rodahl & Davies (1949)	20
Canis familiaris husky	2 700–24 400	Southcott *et al.* (1971)	9.04
Mirounga leonina southern elephant seal	1 080–1 240	Southcott *et al.* (1971)	1.148
Arctocephalus pusillus doriferus Australian fur seal	360–15 000	Southcott *et al.* (1974)	41.67
Arctocephalus pusillus pusillus (South African) Cape fur seal (batches)	785–19 924	Shaughnessy (1981)	25.38
Neophoca cinerea Australian sea lion	79–11 964	this paper	151.4

perature (initially in solid CO_2, and later by continuous refrigeration).

Shaughnessy (1981) recorded the vitamin A levels for the batches of liver harvested over 1941-1949 for the Cape fur seal. The range of estimates made is shown in Table 4. While admitting that in some cases the methods of preservation of the harvested seal livers may not have been ideal, and hence the levels could have been reduced by some decomposition, he was nevertheless able to draw valuable conclusions on factors which could influence the hepatic levels of vitamin A in *Arctocephalus p. pusillus*. In that series of bull seals they were: (1) the maturity of the individual; (2) the vitamin A level of the prey species of fish (hake, *Merluccius* spp.,); and (3) the distance from a pre-determined point on the South African coastline.

In the case of one colony of the Cape fur seals (at Cape Cross) the age of the animal was considered the most important factor influencing the vitamin A level in the liver (Black *et al.* 1945).

In southern Australia Southcott *et al.* (1974) studied the relationships between length, weight and hepatic vitamin A content of a series of 30 specimens of the Australian fur seal, *Arctocephalus pusillus doriferus*. These consisted of 6 males and 24 females. In the case of the 24 females a significant trend was found of increasing hepatic vitamin A storage with increasing age of the animal ($P<.02$). When these data were combined with the data for the 6 males, the presence of such a relationship at a customary level of significance could not be established. There is thus good evidence that the hepatic vitamin A levels in seals are subject to various influences, such as that of age, location and food resources.

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THE NEREIDIDAE OF SOUTH AUSTRALIA

BY P. A. HUTCHINGS & S. P. TURVEY

Summary

Eleven new species of nereid polychaetes from South Australia are described: Ceratonereis amphidonta n.sp., C. pseudoerythraeensis n.sp., C. transversa n.sp., Namanereis littoralis n.sp., Neanthes biseriata n.sp., N. isolata n.sp., N. uniseriata n.sp., Nereis bifida n.sp., N. cirriseta n.sp., N. spinigera n.sp., and N. triangularis n.sp. Two additional new species, Nereis maxillodentata n.sp. and N. parabifida n.sp. are described from New South Wales. Nereis heirissonensis and N. jacksoni are redescribed. Diagnostic descriptions are given of known species of nereids occurring intertidally in South Australia. A key is provided.